June, 1924 Circular No. 282

UNIVERSITY OF ILLINOIS
AGRICULTURAL COLLEGE AND EXPERIMENT STATION

Vitamins in Live-Stock Feeding

By H. H. MITCHELL and M. HELEN KEITH

If animals do not have enough vitamins, they become unthrifty and show signs of indigestion, loss of appetite, nervous disorders and sterility; or definite diseases, such as rickets and paralysis.

Animals consuming large amounts of fresh green roughage or well-cured hays, and exposed to direct sunlight, will probably never be undernourished with respect to vitamins.

Swine, and more particularly poultry, may, under certain conditions, become unthrifty and diseased, because of a deficiency of vitamins in their rations. In most cases, such conditions may be corrected by a more careful selection of natural feeds, and by allowing free access to direct sunlight. Sunlight filtered thru glass is not effective. Commercial vitamin preparations are not needed if such measures can be taken.

URBANA, ILLINOIS

THE study of vitamins is so recent and information concerning them is so incomplete that the popular attitude toward the whole subject ranges from outright disbelief that such factors exist at all to an idea that all other food nutrients are of secondary importance to vitamins. However, any one having a first-hand acquaintance with investigations along this line must realize that vitamins do actually exist, that they occur in foods and feeds in extremely small quantities, that they are required by animals in minute amounts, and that when this minute requirement is not satisfied, malnutrition, if not acute or chronic disease, is sure to follow.

While it is idle to deny the existence of vitamins or the urgent necessity of supplying vitamins in some form to farm animals, it is not necessary, on the other hand, to go to the extreme of believing that vitamins are of paramount importance in nutrition or that the benefits derived from them may be indefinitely increased by increasing the amount fed. Some commercial concerns have fostered such a belief and have put upon the market for both human and animal consumption various preparations purporting to be rich in one or all of the vitamins. They have urged the necessity for their use, even claiming that the human race, and probably all animals as well, may be almost miraculously cured of many obscure ailments by the eating of vitamins.

In view of the claims made, the feeder has been led to question whether the ordinary farm feeds will supply fully the vitamin needs of farm animals, or whether some vitamin concentrate should be purchased and fed in order to safeguard the health of his animals. It is the purpose of this circular to present some general information concerning the nature and distribution of vitamins, together with certain deductions and recommendations that seem to be warranted relative to the balancing of farm rations with respect to them. The facts, as given in this circular, show that careful selection of natural feeds is usually all that is necessary. With one or two possible exceptions, the stock feeder need not spend money on the purchase of vitamin condiments.

Vitamins in Live-Stock Feeding

By H. H. MITCHELL, Associate Chief in Animal Nutrition, and
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Little is known of the nature of vitamins because they are present in natural products in such very small amounts that thus far no one has been able to isolate any of them in a sufficiently pure condition for study. That there are several different vitamins present in foods is evident from the various effects on animals which result when they are lacking in the ration. The different vitamins are distinguished: (1) by differences in the symptoms produced when one or another is deficient in the ration, (2) by differences in solubility and in stability to heat and oxidation, and (3) by differences in occurrence in foods and food products. These vitamins have been called provisionally vitamins A, B, C, etc., until more appropriate names may suggest themselves as more is known of their chemical nature.

Since a deficiency of a certain vitamin in the ration generally produces in an animal a more or less well-defined disease, a system of naming vitamins, based upon this fact, is also in use. An absence of vitamin C in the diet produces in certain animals, including man, a disease called scurvy. Vitamin C is therefore frequently called the anti-scorbutic vitamin. Similarly, the anti-rachitic vitamin protects an animal against rickets (rachitis). This vitamin has not universally been assigned a letter; so it is best known by this name.

Vitamins Are Manufactured by Plants Only

Vitamins are not produced in the animal body. What vitamins are found in the animal body have been stored there, not produced there. The quantity of vitamin contained in animal tissues depends primarily upon the ration fed. If the ration is high in vitamins, the animal may store considerable amounts; if it is low in vitamins, no considerable storage is possible.

Animals have a surprising capacity for storing vitamin A and the anti-rachitic vitamin, but a limited capacity for storing vitamins B and C. Such stored vitamins are found in greatest concentration in the internal glandular organs, such as the liver and kidney. The ordinary cuts of meat, containing all of the well-characterized vitamins, are not good sources of any one of them. Animal body fats contain vitamin A in variable amounts, depending upon the character of the diet and to some extent, apparently, upon the species of animal. Milk may contain relatively large amounts of vitamin A in its fat fraction, but under no conditions is its content of vitamins B and C exceptionally high. Milk cannot be considered an exceptionally good source of vitamin A or of the anti-rachitic vitamin.

Green plant tissues, particularly green leaves, are with few exceptions the best sources of vitamins known, being rich in all the vitamins with the exception of the anti-rachitic.

Seeds in general are reliable sources of one vitamin only, vitamin B. This vitamin is concentrated in the germ (the embryo) and is present to a less extent in the outer coats of the seed. The embryo may contain vitamin A also, but the amount is variable and in no case high. Vitamin C is not to be found in any demonstrable amount until the seed germinates. Indeed, so far as can be determined, seeds may be entirely devoid of vitamins A and C. Their content in the anti-rachitic vitamin is largely unknown.

A Lack of Vitamin A Retards Growth and Injures the Health

Vitamin A, known also as the fat-soluble vitamin, is a growth vitamin; that is, it is required in much greater amount by growing animals than by adult animals. If there is a deficiency of vitamin A in the ration of young animals, their growth will be stunted and their general stamina affected. The animal will have less power to meet the demands of reproduction and lactation, and will be less able to resist disease and infection, particularly of the respiratory tract. Among certain species of animals (rats, dogs, rabbits, poultry, and probably others), the tissues of the eye seem to be particularly sensitive to a deficiency of vitamin A, with the result that eye soreness (ophthalmia, see Fig. 1) and blindness develop as more or less characteristic symptoms. However, animals may die from a deficiency of vitamin A without developing any eye symptoms whatever. The pig on a ration so low in this vitamin as to produce marked symptoms of malnutrition and even cause ultimate death does not, in the experience of the Illinois Agricultural Experiment Station, develop ophthalmia.

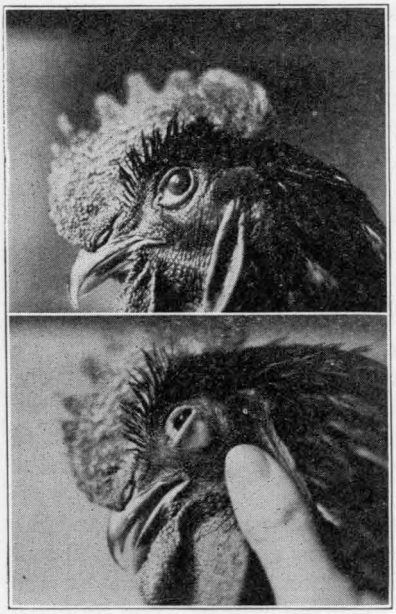

FIG. 1.—OPHTHALMIA (SORE EYES) RESULTING FROM A DEFICIENCY OF VITAMIN A IN THE RATION

The upper picture shows the first symptom—an opaque condition of the false eyelid. The lower picture illustrates a more advanced condition. At this time the eyes are extremely sensitive to light. In obtaining the picture it was necessary to force the eye open.

Green Feeds and Certain Animal Fats Are Rich in Vitamin A

As the name "fat-soluble" vitamin implies, vitamin A is often associated with fat—but mainly animal fats, particularly cod-liver oil, egg-yolk fat, and the butterfat of milk. Good cod-liver oil is by far the richest source of vitamin A now known. Certain animal organs, including especially the liver and kidney, also contain relatively high concentrations of this vitamin. The large majority of vegetable fats contain no demonstrable amounts.

Fresh green vegetation supplies relatively large amounts of vitamin A. The greatest amount is found in the leafy parts of growing plants, probably because it is here that the plant manufactures its food material. Alfalfa and clover leaves, green pasture grass, and green cabbage and lettuce leaves are excellent sources of vitamin A. Carefully cured hays made from plants not too mature also seem to be exceptionally rich in this vitamin. In general, however, if the feed is not eaten while fresh it does not supply its maximum amount of vitamin A, because the processes of drying and curing, particularly with prolonged exposure to the weather, may destroy the vitamin to a greater or less extent; in fact, alfalfa hay, bleached by long exposure, may contain none of this vitamin. For that reason winter rations are less rich in vitamin A than summer rations. The amount of vitamin A in body fats, in cellular tissue (liver), and in milk has been shown to bear a direct relation to the amount of the vitamin in the ration; butter made in the winter, for example, contains only traces of the vitamin.

As already stated, seeds in general are not good sources of vitamin A, tho Japanese millet, yellow corn, and soybeans seem to rank fairly high in this respect. Barley, oats, wheat, rye, rice, and white corn are relatively poor sources of vitamin A, if they contain any at all. No vitamin A has been found in certain varieties of white corn (Iowa Silver Mine, for instance) and certain samples of oats. Some seeds vary a good deal in their vitamin content.

It is of interest to note that while white corn seems to be the poorest source of vitamin A among all cereals, yellow corn is a moderately good source. Different varieties of peas show the same relation between yellow coloring and their content of vitamin A. Among roots and tubers, also, vitamin A seems to be present where there is yellow color, yellow carrots and yellow sweet potatoes containing more than the white varieties and also more than sugar beets and white potatoes. Among different varieties of millet, and among vegetable and animal oils, however, no relation appears to exist between yellow coloring and a high content of vitamin A.

The separation of butter fat removes most of the vitamin A contained in milk. Butter and cream, and cheese made from whole milk are therefore excellent sources of vitamin A. The condensing, evapor-

ating, and drying of milk does not seem to reduce its content of vitamin A to any considerable extent.

While the milling of wheat and rice tends to concentrate in the by-products sold for stock feed such amounts of vitamin A as are present in these seeds, it is doubtful whether even these by-products can be considered good sources of vitamin A. Little experimental evidence is available to settle the question definitely. Wheat bran appears to contain appreciable amounts of vitamin A. However, most of the vitamins of wheat are probably concentrated in the product known as red dog flour, since it contains most of the embryo.

Exposure to Air and Heat Gradually Destroys Vitamin A

Any handling of natural food products which involves prolonged exposure to air reduces the content of vitamin A, apparently thru the chemical action of the oxygen of the air. The rate of such destruction is increased by exposure to sunlight or to high temperatures. For example, in the making of tankage from packing-house wastes any vitamin A which may be contained in the original material is largely or completely destroyed by the intense heat used in rendering the fat and by the exposure to heat and to currents of air in the drying process. The experience of the authors in finding tankage markedly deficient in vitamin A has recently been confirmed at the Ohio Agricultural Experiment Station, where it was also found that fish meal and blood meal cannot be depended upon to furnish this vitamin.

While timothy, clover, and alfalfa plants, especially if immature, may be rich in vitamin A, the hays prepared from them have a lower vitamin content, owing to exposure to sun and weather. If carefully cured, however, no appreciable destruction of vitamin need occur.

Modern methods of refining cod-liver oil do not seem to affect its content of vitamin A, since, by excluding air, changes due to oxidation may be avoided.

A Lack of Vitamin B Affects the Nervous System

Vitamin B is known both as the anti-neuritic vitamin and as a growth vitamin. There is some evidence that more than one vitamin is involved in what is known as vitamin B, but if there are two they are so similar in properties and in distribution among food products that for all practical purposes they may be spoken of as vitamin B.

Vitamin B is undoubtedly necessary for the maintenance of life and vigor at all ages. A lack of it promptly prevents growth, impairs the appetite, affects the organs of digestion and reproduction, and causes malnutrition, particularly of the nervous system. In the later stages of this type of undernutrition, nerve inflammation and degeneration often develop, causing partial or complete paralysis of the hind quarters and in poultry even more characteristic symptoms. In human nutrition

a lack of vitamin B will ultimately cause a disease known as beri-beri, which is particularly prevalent in the Orient. In animals a similar disease, known as a neuritis or a polyneuritis, results from a lack of vitamin B; hence the name anti-neuritic vitamin.

Vitamin B Occurs in All Natural Foods

Vitamin B is the most widely distributed of all vitamins. All naturally-occurring food materials contain it, and of the food materials used in live-stock feeding there is no reason to suspect that any, except a few industrial by-products, are markedly deficient in it. It is impossible to induce polyneuritis in animals when the ration is made up of natural foods. On the other hand, rations made up largely or entirely of milled cereals, such as patent white flour, degerminated corn meal, and polished rice, readily induce this disease in all animals.

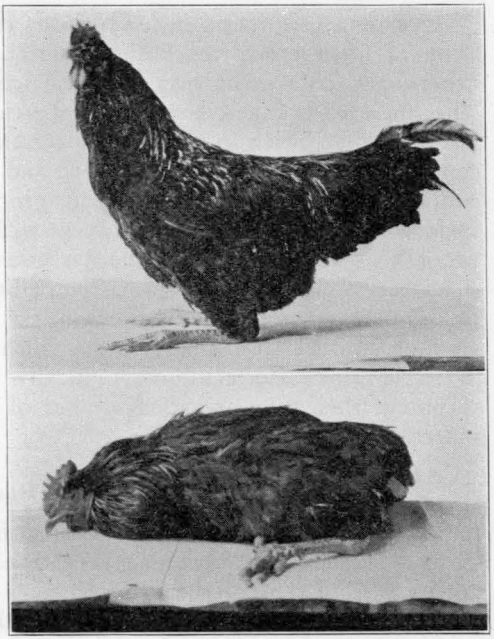

FIG. 2.—RESULTS OF VITAMIN B DEFICIENCY
The bird in the upper picture illustrates the first symptoms of leg weakness. The bird in the lower picture is in the final stages of the disease.

Green plant tissue is exceedingly rich in vitamin B, and since the process of drying does not destroy this vitamin to any great extent, hays are also good sources. The grains are fairly rich in it, the germ of the seed being an exceptionally good source. Yeast (especially brewers' yeast) and wheat germs are standard sources of vitamin B in animal experimentation in nutrition laboratories.

Among the feeds which must be graded as poor sources of vitamin B are tankage, fish meal, and blood meal.

Vitamin C Protects Against Scurvy

The only function of vitamin C in the animal body seems to be to protect against scurvy. It is therefore called the "anti-scorbutic" vitamin. Scurvy occurs frequently among human beings when only preserved foods are available, as on long ocean voyages, on military

campaigns, on polar explorations, or in a besieged city. Monkeys are also subject to this disease, as are guinea pigs. Guinea pigs are generally used in the experimental studies of this vitamin.

So far as has been learned, farm animals are not susceptible to scurvy; at least they have been successfully reared from weaning to maturity on rations that would cause scurvy in guinea pigs in the course of three or four weeks. It has been proved definitely that chickens and pigs are not harmed by a lack of vitamin C in the diet.

Vitamin C Is Found in Relatively Few Foods

Vitamin C is found in fewer foods than any of the other vitamins. Only in fresh green vegetable material, fresh fruits, fresh roots and tubers, and to a much less extent in fresh animal tissues, is it found. The juices of oranges, lemons, raspberries, strawberries, and tomatoes are particularly rich in it. In tomatoes the vitamin remains active after canning, because of the acid present and because the material is out of contact with air during the canning process. Acid fruit juices may be boiled or even evaporated to dryness without losing their anti-scorbutic property. In foods in which there is no such acid, however, the vitamin is lost even on drying at a low temperature. Hays, straws, and dried fodders, therefore, do not contain the vitamin in any appreciable amount, tho the fresh plants from which they were made may be rich in it. Grains also contain practically no vitamin C, except when sprouted; then they are good sources of it. Silage seems to be a poor source of this vitamin.

Rickets and the Anti-Rachitic Vitamin

Experiments with animals during the last few years have shown clearly that rickets (rachitis) is a disease caused mainly by faulty nutrition; that it is produced in growing animals by the continued use of rations ill-balanced with respect to calcium (lime) and phosphorus, and deficient in a fourth vitamin called the anti-rachitic vitamin. On such rations there is a marked disturbance of the concentration of phosphorus or calcium in the blood, and a failure of these elements to deposit in the bones. The bones thus fail to harden, or calcify, a fact that may be clearly revealed by an X-ray photograph (see Fig. 3).

Rickets seems to be a disease confined to civilized races and to domesticated animals. Savage races living under what may be called "natural" conditions do not have rickets, nor do wild animals. It seems to be associated, therefore, with artificial conditions of living. It is widely prevalent among children; it is rather common among pigs, lambs, kids, and puppies, and less common among calves, colts, and rabbits. Among chickens it may occur under certain conditions. Leg weakness in young chicks which are early hatched and grown indoors on rations not containing fresh green material is probably a form of rickets.

The anti-rachitic vitamin also is a fat-soluble vitamin and, so far, has been found in greatest concentration in animal fats. Cod-liver oil is particularly rich in it, and is known to be an excellent remedy for rickets. Egg-yolk also has been reported as effective, tho in less degree, and whole milk and meat in still less degree. Coconut oil contains the anti-rachitic vitamin in relatively slight amounts, tho other vegetable oils, such as olive oil and linseed oil, seem to be entirely free from it. The distribution of the vitamin in the plant world is almost entirely uninvestigated. Some recent work has failed to show any anti-rachtic potency in spinach, tho this is an excellent source of vitamins A and B. Also, at the Wisconsin Agricultural Experiment Station fresh green clover and fresh green cabbage leaves have not proved effective with growing chickens in correcting rachitic rations.[1]

The anti-rachitic vitamin is rather sharply distinguished from vitamin A, with which it is generally associated in animal fats, by the fact that it is little affected by heat and exposure to the air. Cod-liver oil may be kept at the boiling point of water for 20 hours, and may have air forced thru it at a rapid rate during this time, without apparently affecting its anti-rachitic value, tho its content of vitamin A will be entirely destroyed.

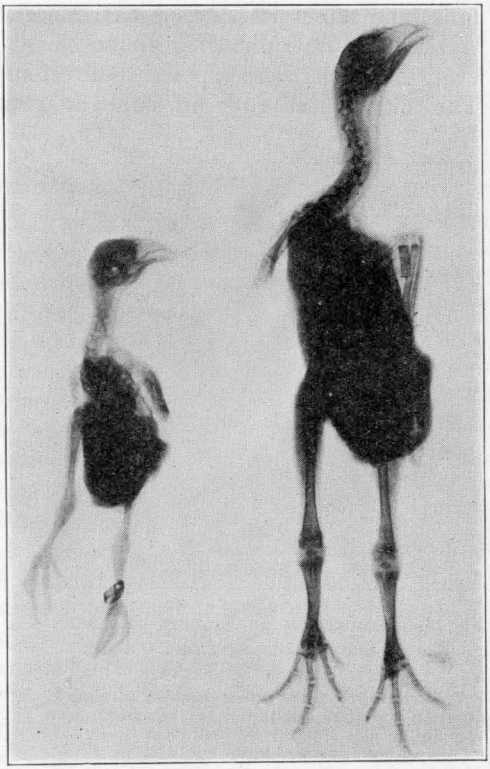

FIG. 3.—DEFECTIVE CALCIFICATION OF BONES IN RICKETS

A radiograph of the two chicks shown in Fig. 4. The bird on the left (No. 3) received the synthetic ration plus green plant tissue, while the bird on the right (No. 8) received the same ration plus one-half hour daily of exposure to sunlight. Normal calcification of the skeleton of No. 3 had not taken place. The patella and metatarsus are but dimly outlined. In the case of No. 8 the skeleton is sharply outlined and great improvement in calcium and phosphorus deposition must have occurred. (Courtesy of Dr. H. H. Steenbock and of the Journal of Biological Chemistry.)

[1]In the experiments with fresh green clover, this material was consumed in amounts equivalent to 5 percent of the total ration, on the dry basis. In other experiments, free access to fresh green cabbage leaves failed to correct the ration and to protect against leg weakness.

Sunlight Is a Substitute for the Anti-Rachitic Vitamin But Not for Vitamin A

An interesting fact of great practical importance is that exposure of animals to direct sunlight may serve the same purpose in promoting growth as the anti-rachitic vitamin. Experiments with rats, babies, puppies, and chickens have established this fact. (See Figs. 3 and 4.) For example, at the Wisconsin Station a ration of white corn, skim milk, and minerals (calcium carbonate and salt) produced rickets (leg weakness) very quickly in young chicks kept in the dark. When, however, the chicks were exposed to direct sunlight, rickets did not develop.[1] The ultra-violet rays in sunlight seem to be entirely or largely responsible for this beneficial action, possibly by enabling the animal to manufacture the anti-rachitic vitamin. These rays will not pass thru window glass, so that direct exposure to sunlight is essential for this effect.

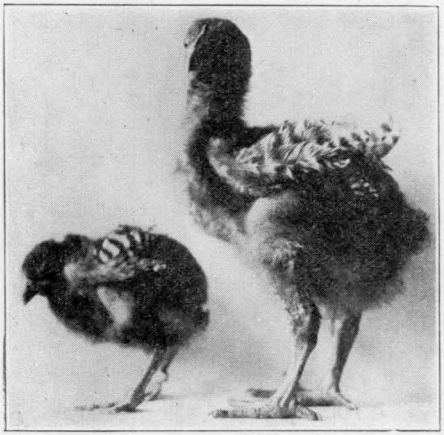

FIG. 4.—COMPARISON OF EFFECTS OF GREEN PLANT TISSUE AND SUNLIGHT ON THE DEVELOPMENT OF RICKETS

Both chicks received a ration composed of alcohol-extracted casein 18, dextrin 60, salt mixture 5, agar 2, yeast 15, plus 5 percent of fresh green clover, calculated on the basis of the dry weight of the clover. After 3 weeks on this ration the bird on the right was exposed daily for one-half hour to direct sunlight. The photographs were taken on the 51st day of the experiment, at which time the bird on the left weighed 95 gms. and that on the right weighed 235 gms. (Courtesy of Dr. H. H. Steenbock and the Journal of Biological Chemistry.)

The above ration is known to contain small amounts of vitamin A. At the Illinois Agricultural Experiment Station quite different results have been obtained with a ration probably more deficient in both vitamin A and the anti-rachitic vitamin than the one used at the Wisconsin Station; namely, a ration of white corn, wheat bran, and tankage. On this ration, young chicks developed ophthalmia, a symptom of vitamin A deficiency, and lived for only a few weeks. Under these conditions no benefit resulted from exposure to ultra-violet light. This observation, considered with the work at the Wisconsin Station, shows a marked difference between the functions of these two fat-soluble vitamins in the animal body, the ultra-violet rays being a substitute for

[1]It is to be noted that in this case rickets, or a disease closely resembling rickets, was produced on a ration which was apparently well balanced with respect to minerals. That the disease actually was rickets is indicated by the facts (1) that light exerted a marked protective effect, and (2) that the same ration has produced abnormally low values for the inorganic phosphorus in the blood as compared with that of birds receiving cod-liver oil in addition.

the anti-rachitic vitamin, but not for vitamin A. Work in other laboratories also has shown that sunlight is not a substitute for vitamin A in animal nutrition.

In this connection it may be mentioned that if cod-liver oil be added to the ration of white corn, bran, and tankage, growth is just as good in absolute darkness as in light, either diffused sunlight or ultra-violet light. Evidently when animals are being raised on good rations the effect of light on growth is not appreciable. As a hygienic factor in relation to all animal life, sunlight is, of course, of great importance, if only because of its powerful antiseptic effect on disease germs. Exposure of bacteria to direct sunlight for only a few seconds is sufficient to kill them.

Dairy Cows in Milk Need a "Fresh-Grass" Vitamin

There is some experimental evidence that dairy cows are also in need of a vitamin to aid in the proper assimilation of the increased amounts of calcium (lime) needed for milk production, and that such a vitamin is supplied in fresh green grass.

During the first part of the lactation period, it is difficult with good-producing cows and impossible with high-producing cows to cover their greatly increased food requirements even by the liberal offering of well-balanced rations. During the weeks immediately following freshening such cows are therefore in a state of undernutrition and in consequence lose weight steadily. In a few weeks, however, either because of an increasing appetite and increasing food consumption, or of a decreasing milk production, a balance is reached between body needs and food consumed, and the animal is able to maintain a constant weight, and, later in the lactation period, even to increase in weight.

While the foregoing statement applies to the total food needs of the cow it does not seem to apply to the mineral needs. Up to the very last stages of lactation a good-producing cow may not assimilate enough minerals, particularly calcium, to maintain a balance with the outgo of minerals in the milk and in the body excretions. During the first half or more of her lactation period a good cow may thus be compelled to withdraw calcium from her skeleton at a constant and considerable rate. This failure of the good dairy cow to meet her calcium needs while producing milk may occur even on good rations, containing liberal amounts of legume hay; and the condition is not greatly improved by the addition of good mineral supplements to her ration. The situation is the result, not of an insufficient intake of calcium, but of the failure of the cow to assimilate enough calcium to meet the enormously increased demand of her mammary glands. While her milk production is high, the calcium of the skeleton apparently is much more readily available than the calcium of the feed. This heavy drain of calcium from the bodies of cows giving large amounts of milk thruout a pro-

longed lactation period has been thought a probable explanation of the frequent loss of breeding capacity by such cows.

Recent experiments have indicated that when dairy cows are on winter rations their power to assimilate calcium may be greatly improved by including fresh green forage in the ration or possibly carefully cured legume hays. That there is a "fresh-grass" vitamin which helps the active mammary gland to take up calcium seems likely from these experiments. It has been suggested that this is the anti-rachitic vitamin, but the fact that it apparently is so readily destroyed by drying and exposure to air, while the anti-rachitic vitamin shows such great stability under these conditions, makes this improbable. Furthermore, fresh green vegetation does not seem to contain appreciable amounts of the anti-rachitic vitamin.

These experiments, indicating strongly the need of a "fresh-grass" vitamin by dairy cows in milk, help to explain why good green pasturage has so beneficial an effect on milk production and give added significance to the use of pasture in the management of dairy herds.

Little Danger of Vitamin Deficiency in Rations of Cattle, Sheep, and Horses

While grains and grain by-products are notoriously ill-balanced feeds with respect to minerals, protein, and vitamins, fresh green forage and good hays, particularly legume hays, are rich in minerals, fairly rich in protein, and as already stated are good or excellent sources of vitamins A and B. Roughages are thus excellent supplements to the grains and their by-products, the combination of the two in proper proportions giving a complete and adequate ration in all respects.

Since vitamin C is not needed by farm animals, its deficiency either in grains or in dried roughages is not a matter of concern on the farm. With most farm animals, as ordinarily reared on the farm, a deficiency of the anti-rachitic vitamin in the ration may not be a matter of great concern, since direct sunlight is such an efficient substitute for it.

It appears probable, therefore, that cattle, sheep, and horses, fed rations containing large amounts of good roughage and having access to green pasturage during part of the year, are in little danger of being inadequately nourished if good judgment is used in balancing their rations with ordinary feeds grown on the farm or procurable in the open market. With these animals any special balancing of their rations with respect to vitamins is unnecessary. The case of the dairy cow in milk, which has just been discussed, is perhaps exceptional.

Swine and Poultry Are the Most Likely to Be Undernourished with Respect to Vitamins

Well-balanced rations for swine and poultry are not so easily obtained. Because of the nature of their digestive tracts, these animals

must be fed rations made up largely of grains, grain by-products, and concentrated feeds of equally ill-balanced character, such as oil meal.

The necessity of balancing swine and poultry rations with respect to protein has led to an extensive use among progressive live-stock farmers of such protein concentrates as oil meal, gluten feed, tankage, meat scraps, blood meal, and skim milk or buttermilk. The further need of adding minerals when the protein concentrate does not also add enough of these nutrients is beginning to be realized and is leading to the use of good mineral supplements, such as bone preparations, high grade limestone, and acid phosphate. The free offering of minerals (oyster shells, for example) to laying hens is a common practice.

The need of balancing the grain rations both of swine and poultry with respect to vitamins is not generally realized. This need is much greater with poultry than with swine, since the vitamin requirements of growing poultry are much greater in proportion to the total food requirements than those of growing pigs. This is illustrated by the fact that chickens develop symptoms of deficiency diseases in a much shorter time than pigs on rations deficient in vitamins, and live for a much shorter period of time on such rations.

The danger of vitamin undernutrition among poultry is probably much greater than among any other species of farm animals. The extreme results of vitamin deficiencies among poultry, the so-called "deficiency diseases," are briefly described in the following pages and the conditions leading to such diseases discussed. However, the importance of vitamins in maintaining the health and normal development of a flock of poultry is undoubtedly much greater than the occurrence of deficiency diseases might indicate. It should be remembered that these diseases are simply the *final* results of the continued use of rations too low in vitamins. Long before the characteristic symptoms of deficiency appear, the birds may show signs of ill health and malnutrition if the rations are only moderately low in their vitamin content. Impaired appetite, digestive disorder, diarrhea, colitis, low temperature, anemia, and general lack of thrift and vigor may be due to rations badly balanced with respect to vitamins.

The effects of rations poor in vitamins are described by one investigator, McCarrison, after extensive experience in India, in the following words: "It is no doubt of great importance to be aware that food deficient in certain vitamins will ultimately cause nervous symptoms [for example] of a definite order. But since these are end results, it is of still greater importance to realize that the same faulty food will give rise more early to gastro-intestinal disturbances and other forms of vague ill-health, and that these like the nervous symptoms, can be prevented by supplying the necessary vitamins and adjusting the balance of the food." In the same connection the possibility may be mentioned that a ration on the border line with respect to its

vitamin content, may become distinctly deficient in this respect if the flock is infected with intestinal parasites, since the parasites may rob their host of enough vitamin so that distinct symptoms of a deficiency disease will result.

Vitamin B May at Times Be Deficient in Grain Rations for Poultry

Vitamin B is so widely distributed among natural foods that there is, in general, little danger of a lack of it in practical feeding operations on the farm. Since it is found in considerable amounts in grains, grain rations are not conspicuously ill-balanced with respect to it. There is no indication, for example, that swine on any common ration would receive too small an amount of vitamin B.

With chickens there is some evidence that the amount of vitamin B in some of the grains is not large enough to cover fully the requirement. This seems to be definitely true of oatmeal, according to recent experiments in England. It is possible, therefore, that when green feed is not available, a deficiency of vitamin B in poultry rations may exist. This would be particularly true in late winter or during a very hot, dry summer. While a severe deficiency disease (polyneuritis) probably would not result, chronic undernutrition, lack of thrift, digestive disturbances, and leg weakness might develop more or less generally in a flock of young chicks, or possibly among older birds, under such conditions, and even occasional deaths may occur. The feeding of yeast should be beneficial in correcting or preventing such difficulties.

Ducks, geese, and turkeys seem to have an even greater need for vitamin B than do chickens, and would probably break down sooner than chickens on rations not supplemented by green feeds. Pigeons, on the other hand, seem to have less need for this vitamin than chickens.

The Fat-Soluble Vitamins Are Generally Deficient in Grain Rations for Poultry

A deficiency of vitamin A in poultry rations may be expected whenever green feed is not available. The effect of such a deficiency varies primarily with the age of the bird. The younger the bird the more intense is its requirement for this vitamin and the sooner will symptoms of malnutrition develop. Young chicks fed from the time of hatching, or shortly thereafter, on a ration having practically no vitamin A, such as a ration of white corn, wheat bran, and tankage, will, in two to six weeks, succumb to a deficiency disease. They will all show the symptoms, collectively described as "leg weakness," which include an impaired appetite, an anemic condition of the comb and wattles, drooping wings, ruffled feathers, an unsteady gait culminating

in total inability to stand, and frequently a diseased condition of the eye, called ophthalmia. Tho ophthalmia may be absent or not so pronounced in young birds dying shortly after being placed on a ration severely deficient in vitamin A, it is the most characteristic symptom of this deficiency disease. The outward symptoms resemble those of roup, and the disease has been called "nutritional" roup.

If permanent injury has not been done, the above disease may be readily cured by feeding cod-liver oil. Its prevention is assured by giving the chicks ready access to green feed, such as green cabbage or lettuce leaves, fresh alfalfa or clover, or sprouted oats. Tomatoes, either fresh or canned, would also serve the purpose well. Feeding cod-liver oil to young chicks during the first few weeks of life, when green feed may not be readily obtained, may prove to be an economic practice. One to 2 percent of cod-liver oil in the mash may be recommended in such cases.[1] The difficulty has also been overcome by feeding eggs to young chicks at the rate of one egg daily to thirty chicks. The eggs should be beaten up with skim milk and the mixture worked into the mash.

Mature animals are known to have a lower need for vitamin A than immature animals, so far as their own body needs aside from reproduction are concerned. While a deficiency of vitamin A is not to be expected under ordinary conditions with mature poultry, the laying hen offers a special problem. There is some evidence indicating rather clearly that eggs will not hatch so readily when the hen is given rations low in vitamin A.

In marked contrast to chickens, it is of interest to note that the requirement of pigeons for vitamin A is so low that there is reasonable doubt whether this species of bird needs the vitamin at all.

While practically nothing is known of the distribution of the anti-rachitic vitamin among poultry feeds, rickets has been produced in young chickens on a ration of white corn, minerals, and skim milk. Some of the symptoms described above as being due to too little vitamin A in the ration, particularly leg weakness, probably are symptoms of rickets resulting from a lack of the anti-rachitic vitamin. The raising of young chicks indoors would aggravate such symptoms, while getting them out into the direct sunlight would probably protect them completely from disturbances due to too little anti-rachitic vitamin in the ration.

Grain Rations for Swine May at Times Be Deficient in the Fat-Soluble Vitamins

The requirement for vitamin A by swine is evidently relatively small. The mature breeding sow, so far as her own body needs are concerned, seems to need the vitamin only in very small amounts. On a ration of white corn and tankage, which is practically free from

[1]The oil should be added to the mash each day, since when mixed with a mash, its fat-soluble vitamins are slowly destroyed.

vitamin A, sows will farrow and raise successfully at least two consecutive litters. Eventually, however, the ability to produce young is affected by such a ration.

With growing pigs the demand for vitamin A is somewhat more definite. Pigs put on a ration of white corn and tankage or white corn and skim milk at weaning age can make little growth. If started on such a ration at 60 to 70 pounds weight, they may attain 180 to 200 pounds, but will then frequently go off feed and finish their growth very slowly. Occasionally disastrous results will follow the feeding of such rations, many of the pigs dying before reaching market weight. Cod-liver oil has proved a satisfactory corrective in such experiments. A small amount of alfalfa meal is of distinct advantage, while access to good legume pasture is a safe preventive. Linseed oil meal, wheat middlings, or oats probably would not improve the above ration.

Young pigs are undoubtedly subject to rickets and probably some of the symptoms resulting when rations lacking in vitamin A are fed, are traceable to a deficiency of the anti-rachitic vitamin as well. However, until more is known of the distribution of the anti-rachitic vitamin in vegetable foods, no general statements can be made as to the likelihood of rickets developing under farm conditions.

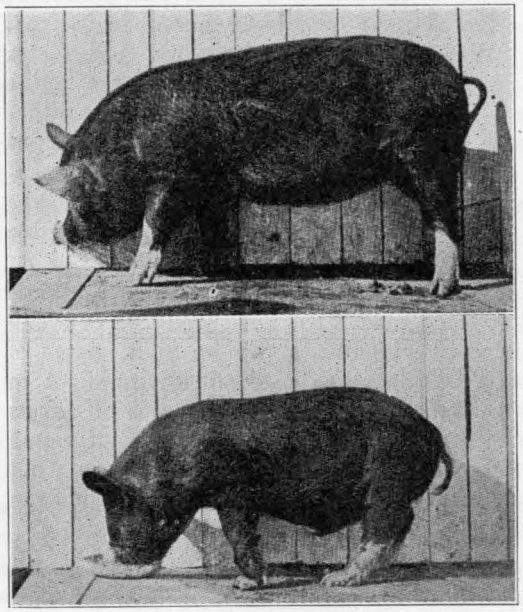

FIG. 5.—THE NEED FOR FAT-SOLUBLE VITAMINS BY PIGS

These pigs are litter mates. The one below was raised on a ration very low in fat-soluble vitamins, consisting of wheat middlings, casein, lemon juice (vitamin C) and yeast extract (vitamin B). The one above received the same ration plus small amounts of cream and later of cod-liver oil. The pictures were taken when the pigs were six months old. (Courtesy of the Biochemical Journal.)

No Apparent Need for Commercial Vitamin Preparations

Since many feeds commonly used in the rations of farm animals have proved to be excellent sources of the various vitamins, no real need for commercial vitamin preparations appears to exist, even tho there were every assurance that such preparations are rich in vitamins. Such assur-

ance, however, cannot be felt with regard to most of the vitamin concentrates prepared on a commercial basis. Actual tests of many of the preparations designed for human use have shown a potency to exist only in the case of vitamin B content of certain of the yeast preparations; and in nearly all these showing any vitamin at all, it was present in much smaller quantities than in dried brewers' yeast or in wheat germs.[1] In the ration of farm animals there could be no reason for the addition of any preparation for the sake of its vitamin B content, with the possible exception of poultry, as has already been mentioned.

Cod-liver oil, as stated above, is an excellent source of vitamin A and of the anti-rachitic vitamin. Since the requirement for these vitamins by growing chicks is so great, it may prove to be a good practice to add this substance to the ground mash, especially in seasons when abundant green feed is not available. It may be used also as an emergency measure in outbreaks of leg weakness in poultry. As already stated (page 16), it is an excellent corrective in the case of young pigs which have been fed rations lacking in vitamin A, such as corn and tankage.

A Summary of the Vitamin Content of Feeds and Farm Products

In the following table an attempt is made to indicate the relative vitamin content of certain farm feeds and farm products for which information is available. The attempt has been made to put the information in as nearly a quantitative form as the experimental results appear to justify. Where considerable doubt has been felt in assigning a given rank to a food material, this doubt is expressed by a question mark, the question mark meaning that possibly the material contains more vitamin than the symbol indicates.

The table is limited to a consideration of vitamins A and B. Information in regard to the distribution of the anti-rachitic vitamin is very limited and is all contained in the text of this circular. The distribution of vitamin C in feeds is not of any practical importance in live-stock feeding until it can be shown that farm animals are in need of this vitamin. Furthermore, reliable information as to the amount that may be present in different food materials is not at hand, except in a very few instances, and all indications point to an extreme variability in the content of many materials in vitamin C. In the text of this circular (page 8) will be found a brief summary of the most important known sources of this vitamin.

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[1]See for example: E. M. Bailey; Bulletin 240 of the Connecticut Agricultural Experiment Station, 1922. J. H. Hess, J. J. Moore, and J. K. Calvin; Journal of the American Medical Association, Volume 73, page 1441 (1922). K. H. Coward and A. J. Clark; British Medical Journal, Jan. 6, 1923, page 13.

Amounts of Vitamins A and B in Farm Feeds and Farm Products

– indicates a lack of information and of any safe basis for estimating the vitamin content
0 indicates no appreciable amounts of vitamin
\+, ++, +++, ++++ indicate increasing amounts of vitamin
★ indicates an exceptionally large amount of vitamin
? indicates that the vitamin content may be higher than the estimate given.

	Vitamin A	Vitamin B
Green forage, dried		
Alfalfa	★	++++
Clover	★	++++
Timothy	★	++++
Cabbage, green leaves	++++	++++
Cabbage, white leaves	+++	++++
Lettuce	★	++++
Carrot tops	★	++++
Spinach	★	++++
Grains and seeds		
Barley	+	+++
Corn, white	0	++++
Corn, yellow	++	++++
Millet	0 to +	–
Oats	0 to +	+++
Peanuts	+	++++[1]
Peas, yellow	++	+++
Peas, green	+++	+++
Rye	+	–
Soybeans	+++	+++
Wheat	+	++++
Seeds, green sprouted	Content of Vitamins A and C increased as compared with ungerminated seed.	
By-products of seeds		
Cottonseed meal	+	+++
Soybean meal[2]	++	+++
Coconut meal	++	+++
Wheat bran	++	+++
Wheat flour, white	0	+
Wheat germ	++ (?)	★
Gluten feed	0 (?)	0
Rice, polished	0	0
Rice bran	0	★
Tomato press cake	++ (?)	++ (?)

[1]This evaluation is assumed on the basis of experiments carried out with several nuts of other kinds.

[2]The values found for soybeans are used here because the process of extraction of the oil is not known to remove or destroy the vitamins.

	Vitamin A	Vitamin B
Roots and tubers, dried		
Carrots, yellow	★	++++
Carrots, white	0 to +	++++
Rutabagas	+	++++
Potatoes, white	+	+++
Sweet potatoes, yellow	++++	++
Sweet potatoes, white	+	–
Sugar beets	0	0 to +
Red beets	0	0 to +
Sugar mangels	0	0 to +
Animal products, dried[3]		
Milk, whole	++++ (?)	+++
Milk, skim[4]	++	+++
Butter	★	0
Eggs	++++	++++
Egg white	0	0 (?)
Egg yolk	★	++++
Meat[5]	+ (?)	+ (?)
Kidney	+++ (?)	+++ (?)
Liver	★	★
Heart	+++	++++
Brain	–	+++ (?)
Tankage	0 to +	0
Blood meal	0	0
Fish meal	0	0
Miscellaneous		
Yeast	0	★
Tomatoes, dried	★	++++
Molasses	0	0
Cod-liver oil	★	0

NOTE.—Since all of the information on the vitamin content of food materials summarized in the above table was obtained thru experiments on rats, the significance of the above signs may be stated more precisely as follows:

\+ indicates that the vitamin content of the food is so low that when it constitutes as much as *85 to 95 percent* of the ration the amount of vitamin it supplies is so low that normal growth in the rat has not been obtained.

++ indicates that the vitamin content of the food is such that when it constitutes from *50 to 85 percent* of the ration the amount of vitamin it supplies seems to be adequate for normal growth in the rat.

+++ indicates that the vitamin content of a ration containing from *20 to 50 percent* of the food, and no other source of the vitamin, seems to be adequate for normal growth in the rat.

++++ indicates that the vitamin content of a ration containing from *5 to 20 percent* of the food, and no other source of the vitamin, seems to be adequate for normal growth in the rat.

★ indicates that the vitamin content of a ration containing only *5 percent or less* of the food, and no other source of the vitamin, seems to be adequate for normal growth in the rat.

To anyone familiar with the nature of the experimental results upon which the table is based, it is obvious that the symbols as defined above should not be taken too literally. The experimental technic in

[3]The vitamin content of animal products, particularly with respect to vitamin A, is subject to considerable variation in accordance with the previous ration of the animal. The values given are probably maximal.

[4]The vitamin content of skim milk is subject to two sources of variation: (1) variation in the vitamin content of the ration, and (2) variation in the completeness of separation of the cream. Neither source of variation would influence greatly its content of vitamin B, but both may modify markedly its content of vitamin A. Thus, it has been estimated by different investigators that skim milk contains from one-eighth to one-half of the vitamin A of whole milk.

[5]Recent work by Hoagland on the anti-neuritic value of different kinds of lean meat for pigeons has indicated a high potency, particularly for lean pork, as compared, for example, with liver and kidney. We hesitate to interpret these results in terms of vitamin B, as it functions in the growth of rats, because Hoagland's results on pigeons are so different from those of Osborne and Mendel on rats. The vitamin content of lean meat needs further investigation before definite statements are warranted.

vitamin investigations has not been quantified or standardized sufficiently so that the results obtained can be said to have a definite and absolute significance.

It should be pointed out also that the different groupings indicated by the different symbols may include substances differing widely in vitamin content. For example, it has been found that when used as the sole source of vitamin B, the quantity of whole wheat or of dried eggs required to promote normal growth in the rat is approximately twice as large as is the quantity needed of dried alfalfa, clover, or spinach. The vitamin B content of all three feeds, however, must be represented by ++++. Similarly, cod-liver oil is a much better source of vitamin A than is butter, one estimate placing its content in the vitamin at 250 times that of butter. The content of both in this vitamin is indicated, however, by the same symbol, i. e.,*.

In determining the vitamin content of food materials containing a large proportion of water, such as fresh green leaves, eggs, roots and tubers, etc., the general procedure has been to dry the material carefully at a low temperature before testing it in feeding experiments. The results given in the table apply, therefore, to the dry substance of the food. In applying them to the fresh foods it must be remembered that green grasses and forage contain from 50 to 75 percent of water and roots and tubers 80 to 90 percent of water. Cows' milk averages 87 percent water, and hens' eggs 75 percent water.

The experiments on which the above information is based were all conducted with rats. A rat will grow normally if its ration possesses a vitamin value represented by ++. It seems probable that the vitamin A requirements of the pig are somewhat less, rather than more, intense than those of the rat. In roughly balancing rations for growing pigs with respect to vitamin A, therefore, by the use of the information tabulated above, the object should be to secure rations with a rating of ++. If feeds are to be used with a vitamin A ration of 0 to +, other feeds must be used with ratings of +++ or more, in amounts sufficient to make good the deficiency of the first feeds.

With chickens the need for both vitamin A and vitamin B, but particularly vitamin A, is probably more intense than that of the rat. The rations of growing chicks would probably need to have an average vitamin rating of +++ or better for both A and B. With respect to vitamin A, it is clear that this rating can be secured under practical conditions only by including liberal amounts of green feed, with ratings of ++++ to *, since most of the rations necessarily must consist of grains with vitamin A ratings of ++ or less. There are some grounds for believing that, with reference to vitamin B, the ration of growing chicks should possess a rating of ++++, with the inclusion under certain conditions of some material with a rating of * as a measure of safety.

UNIVERSITY OF ILLINOIS
AGRICULTURAL COLLEGE AND EXPERIMENT STATION

ABSTRACT OF CIRCULAR NO. 282*

Vitamins in Live-Stock Feeding

BY H. H. MITCHELL AND M. HELEN KEITH

Much is being said these days about the importance of vitamins in the rations of live stock as well as of human beings. The live-stock feeder has been led to question whether ordinary farm feeds will fully supply the needs of his animals or whether some vitamin concentrate should be purchased and fed in order to safeguard their health. The latter idea has been fostered by some commercial concerns purporting to put upon the market condiments rich in vitamins. It is the purpose of this abstract to discuss briefly and in a general way the nature of vitamins and their distribution in farm feeds, and to make certain recommendations for the balancing of farm rations with respect to vitamins.

Vitamins Essential to Health of Animals

Vitamins are substances of unknown chemical composition, occurring in natural food products in extremely small amounts, which are essential to the life and health of animals. So far as is known at present, they are manufactured by plants only.

Animals need vitamins only in extremely small amounts; if the ration is deficient in these substances, animals become unthrifty and show signs of indigestion, loss of appetite, nervous disorders, paralysis, sterility, and soreness of the eyes, or develop definite diseases, such as rickets or scurvy. No chemical test for vitamins is known. Their absence or deficiency in a food or ration is indicated by the appearance of such symptoms as those just mentioned. Their presence in the food in amounts sufficient to cover the animal's requirement, is indicated by an absence of such symptoms. The testing of food for its vitamin content, therefore, cannot be done by chemical analysis, but only by actual feeding experiments with laboratory animals, such as rats, chickens, pigeons, and guinea pigs.

*The complete edition of this circular covers 20 pages, is illustrated, and gives further details regarding the feeds that will supply the different vitamins in adequate amounts for farm animals. It will be sent to anyone who requests it. Address College of Agriculture, Urbana, Ill.

Several Different Vitamins in Foods

That there are several different vitamins present in foods is evident from the fact that the symptoms or diseases mentioned above are each cured by certain definite foods or food preparations. For example, paralysis resulting from faulty diet may be cured by giving very small amounts of yeast or wheat embryo or by extracts made from these products. Eye soreness (ophthalmia) of dietary origin may be cured by whole milk or small amounts of butter, cod-liver oil, or green clover or alfalfa, but not by yeast. Scurvy is cured by eating small amounts of fresh fruits or vegetables or their juices, and rickets by the consumption of small amounts of cod-liver oil, but not by small quantities of green clover or alfalfa.

These different but unknown dietary factors essential for the growth and well-being of animals are called vitamins A, B, and C, until more is known concerning them. The vitamin which protects growing animals against rickets (rachitis), tho sometimes called vitamin D, is more generally spoken of as the anti-rachitic vitamin.

Vitamin A is Necessary for Growth and Health

If a ration is deficient in vitamin A, growth is not possible except in so far as the animal may have stored in its body considerable amounts of the vitamin from rations containing an excess of it. When this store is used up, and the animal is receiving insufficient amounts from its food, growth stops, a decline in weight sets in, and signs of ill health appear. The animal will be less able to resist bacterial infection, especially of the lungs. Among most species of animals so far investigated, the tissues of the eye seem to be particularly sensitive to a deficiency of vitamin A, eye soreness (ophthalmia) and even total blindness developing as a characteristic symptom. If the deficiency of vitamin A is but slight, growth may be completed at a normal or nearly normal rate, but the animal will not have the power to meet fully the demands of reproduction and lactation, and on such a ration, an inferior breeder is produced.

Seeds and their mill by-products are not, in general, good sources of vitamin A. While yellow corn and soybeans rank fairly high in this respect, barley, oats, wheat, rye, rice, and white corn are poor sources of it. Tankage, fish meal, and blood meal must also be classed as poor vitamin A feeds.

Fresh green vegetation supplies relatively large amounts of vitamin A. Alfalfa and clover leaves, green pasture, and green cabbage and lettuce leaves are thus excellent sources of this vitamin. Carefully cured hays are also exceptionally rich sources of vitamin A.

Since vitamin A is required in human nutrition, and particularly in infant nutrition, it is a matter of some importance that dairy cows on rations rich in vitamin A secrete in their milk liberal amounts of this substance. The vitamin A of milk is contained largely in the fat fraction, so that butter is a much better source of the vitamin than is whole milk. On the other hand, if the ration of the cow is poor in vitamin A, the milk is also poor in it, and therefore less valuable as a human food.

Natural Foods Are Rich in Vitamin B

Vitamin B is undoubtedly necessary for animals of all species and ages. A lack of it in the diet prevents growth as soon as the store of the vitamin in the body is exhausted, impairs the appetite, and affects the organs of digestion and reproduction, and particularly the nervous system. If the deficiency of vitamin B is severe, a nervous disease known as polyneuritis will develop, characterized by paralysis of the hind quarters in quadrupeds, and, in chickens, by leg weakness and other symptoms of nerve inflammation and degeneration.

All natural food materials contain vitamin B in quantities sufficient to cover the requirements of most of the species of animals investigated. Green vegetation and good hays are exceptionally rich in the vitamin. Milled flours and packinghouse by-products must be graded as poor sources of this vitamin.

Vitamin C Not Necessary for Farm Animals

If the food supply is deficient in vitamin C, certain animals, including man, the monkey, and the guinea pig, develop a distinct disease called scurvy. However, it appears that farm animals are not susceptible to this disease and hence do not need a supply of vitamin C in their food. Hence, further consideration of this vitamin is unnecessary.

Sunlight a Substitute for the Anti-Rachitic Vitamin

All growing animals seem to be subject to rickets, a disease caused by continued subsistence on a ration ill-balanced with respect to calcium and phosphorus and deficient in the anti-rachitic vitamin. Rickets is characterized by a failure of the bones to harden or calcify. Leg weakness in young growing chicks, kept indoors, is probably a symptom of rickets.

The distribution of the anti-rachitic vitamin among feeds is almost totally uninvestigated. Green vegetation is not a good source of this vitamin if it contains it at all. It is present to some extent in some seeds, in whole milk and butter, in egg yolk, and in fresh meat. Cod-

liver oil is an exceptionally good source of it. However, it is not essential that the rations of growing farm animals contain the anti-rachitic vitamin, since exposure to direct sunlight will correct this deficiency, possibly by enabling the animal to manufacture the anti-rachitic vitamin itself. Exposure to light that has passed thru window glass does not serve this purpose, since ordinary glass filters out the effective rays (ultra-violet).

Recommendations to Live-Stock Feeders

The following recommendations concerning the balancing of farm rations with respect to vitamins seem justified. In making these recommendations it is realized fully that the information upon which they are based is not so complete as may be desired, and that the recommendations may be subject to modification later.

1. *Animals consuming large amounts of fresh green roughage, good pasture, or well-cured hays, and kept out-of-doors, will probably never be under-nourished with respect to vitamins.* Good-producing dairy cows in milk may be an exception to this statement, since it seems that winter rations may be deficient in a "fresh grass" vitamin required for the assimilation of the calcium needed in the production of large amounts of milk. This vitamin has not been identified with any of the vitamins described above. The need of such a vitamin would help to explain the great value of good pasture for dairy cows.

2. *Growing swine may occasionally become unthrifty and diseased because of a deficiency of vitamin A in the ration.* The fertility of brood sows may be lowered for the same reason. If the ration is restricted to such feeds as white corn, oats, wheat by-products, and packinghouse by-products, a deficiency of vitamin A may develop. This can be best corrected by permitting access to good pasture or good hay, or by substituting yellow corn for white.

3. *The requirements of growing chickens and laying hens for all vitamins seem to be more intense than those of swine, so that on grain rations alone, the danger of vitamin deficiency in chickens and hens is greater than with swine.* The importance of green feed and of direct sunlight in the raising of poultry is therefore much greater than in the raising of any other class of live stock.

4. *Since vitamin deficiencies of farm rations can be readily corrected by a judicious use of ordinary feeds, commercial vitamin preparations cannot be recommended for general use.* As an emergency remedy for unthriftiness in poultry due to a lack of vitamin A or the anti-rachitic vitamin, cod-liver oil may be recommended. One to 2 per-cent of it in the mash, added fresh each day, should be sufficient.